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Electronic Sputtering and Desorption Effects in TOF-Secondary Ion Mass Spectrometry Studies using Slow Very Highly Charged Ions like Xe^{44+} and Au^{69+}

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The development of new ion source technologies, such as the Lawrence Livermore National Laboratory Electron Beam Ion Trap (EBIT) [1], has made low emittance ($\leq 1\ \pi$ mm mrad) beams of slow ($v << v_{Bohr} = 2.2 * 10^6$ m/s) very highly charged ions (like Xe^{44+}, Au^{69+}, and in principal U^{92+}) available for ion solid interaction studies [2]. The prominent feature in these interactions as compared to the interaction of singly or modestly charged ions with solids is the dominance of electronic over collisional effects. While single highly charged ions approach a surface, several hundred electrons are emitted from an area of only a few square nanometers [3]. This drastic disturbance of the local charge equilibrium results in very effective electronic desorption of surface adsorbates. E. g. secondary H_2^+ yields from thermal SiO_2 films are found to increase with almost the fifth power of the incident ion charge: $Y(H_2^+) \sim q^{4.8}$ to over 1.5 H_2^+ per incident highly charged ion. The lattice of insulators and modest conductors relaxes in a "Coulomb Explosion" [4] before charge neutrality can be reestablished. Resulting secondary ion yields in highly charged ion solid interactions show an increase over secondary ion yields from collisional processes (using ~300 keV Xe^{q+}, with q=0,1+,2+) of a factor of ~100.

In the example of the interaction of Au^{69+} ions (E_{kin}= 1.4 keV/amu and 3.5 keV/amu) with a SiO_2 target (50 nm thermal oxide on Si), we conclude that more than 35 secondary ions are emitted upon impact of a single highly charged gold ion (assuming a 10% detection efficiency of our TOF-SIMS setup). Highly charged ion induced secondary ion yields alone are thus acceding total secondary particle yields (i. e. neutral and charged) as know from studies of collisional sputtering with singly charged ions (e. g. [6, 7]). Ionization probabilities of secondary particles emitted in highly charged ion solid interactions are currently not known; theoretical studies [5] suggest that charged fractions of secondary particles are about 15% of total secondary particles, experimental studies are being performed. Negative secondary ion spectra from thin SiO_2 films [Fig. 1] show series of SiO_2 clusters, currently detected up to $(SiO_2)_{20}O^-$. The production rate for $(SiO_2)_{10}O^-$ clusters is found to be ~ 2% (assuming ~10% detection efficiency). Corresponding positive secondary ion spectra are dominated by high yields of atomic ions from the sample compound (O^+, Si^+) and any present surface contaminations (C^+).

Strongly increased useful yields, especially of secondary cluster ions, could mark a significant advantage in scanning SIMS at high lateral resolution (sub micrometer pixel size).

In my presentation I will review our current understanding of highly charged ion induced electronic sputtering and desorption processes with a focus on the contribution these new breed of primary ions can make as an analytical tool in SIMS.

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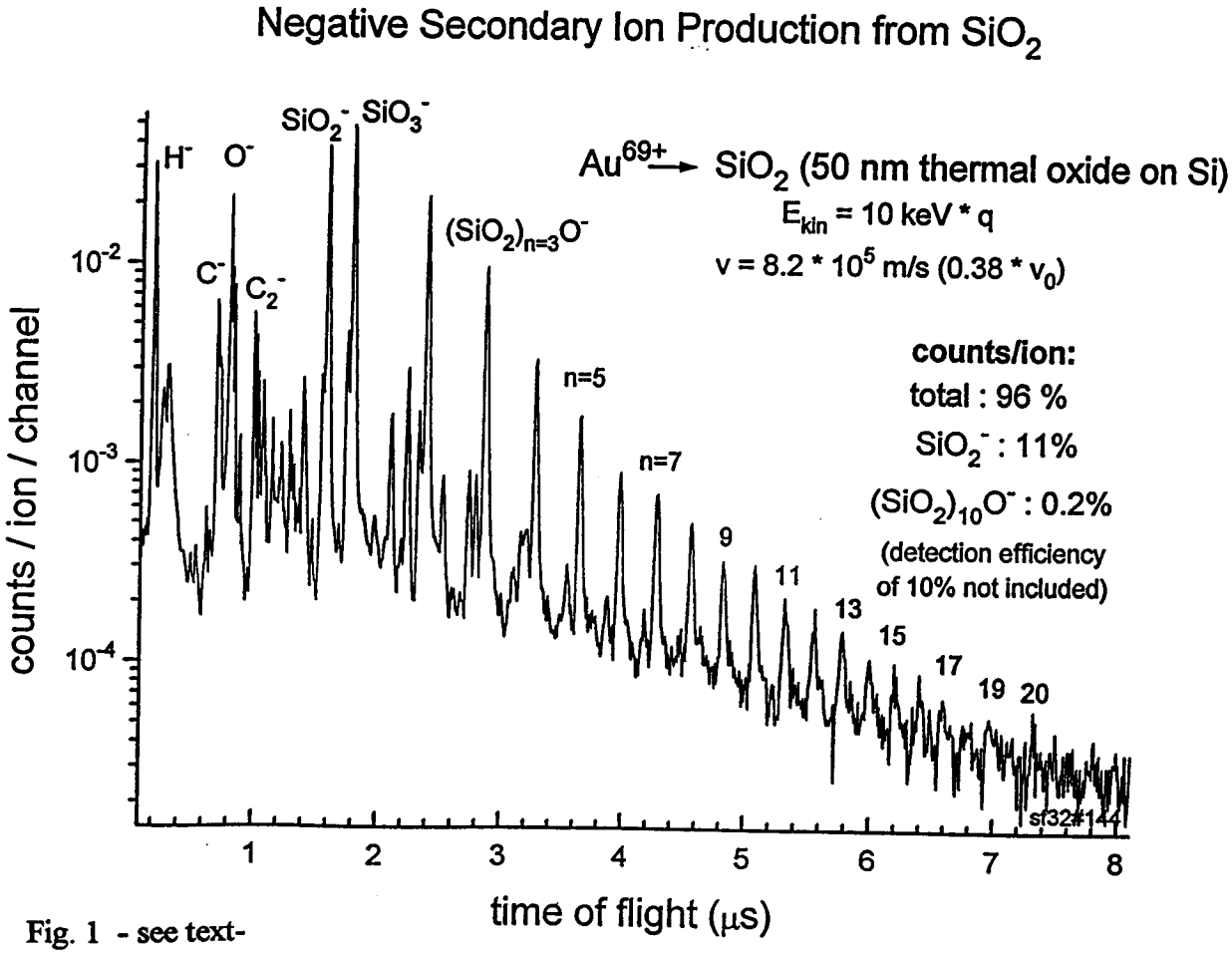

Fig. 1 - see text-